# SHEAR PERFORMANCE OF CONCRETE SLAB WITH THE ADDITION OF OIL PALM SHELL AS LIGHTWEIGHT CONCRETE AGGREGATE

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## Abstract

This thesis deals with the use of waste materials, oil palm shell (OPS) as a replacement for coarse aggregate in the concrete. The objectives of this thesis are to determine the potential of OPS as a coarse aggregate replacement in lightweight concrete and to study the structural behaviour of slab with the addition of OPS. The potential of palm oil by-product, OPS to be used as a replacement of coarse aggregates in the concrete production can be guaranteed. As the cost of raw materials in the concrete industry is getting higher therefore manipulating the waste material is the best way to lessen the cost of concrete. The utilization of OPS in the concrete also helps to solve environmental problem caused by the improper disposal of waste materials. The addition of OPS as a replacement to coarse aggregate produces lightweight concrete which is a very cost effective. The paper reports on the experimental works on the structural behaviour of concrete slab with the addition of OPS. This thesis describes the tests which are to be applied on concrete which are compression test and combined bending and shear test. Concrete specimens involved in this research are cube of size 100 mm × 100 mm × 100 mm and slab of size 350 mm × 500 mm × 100 mm.Three different concrete mix compositions were prepared which were the concrete without the addition of OPS (batch 1, B1), concrete with the addition of 50% OPS (batch 2, B2) and concrete with the addition of 100% OPS (batch 3, B3). The compressive strength of cube specimens was carried out at 7 and 28 days. The results show that the increase in percentage replacement of OPS decreased the compressive strength. Concrete slab specimens were tested at 28 days to observe the failure under the shear load. The results showed that increasing the content of OPS into the concrete slab gives no significant effect to the shear failure load improvement.

## Abstrak

Tesis ini berkaitan dengan penggunaan bahan buangan, tempurung kelapa sawit (OPS) sebagai pengganti agregat kasar dalam konkrit. Objektif kajian ini ialah untuk menentukan tahap potensi OPS sebagai pengganti agregat kasar dalam konkrit ringan dan mengkaji tingkah laku struktur papak dengan tambahan OPS. Potensi hasil sampingan minyak sawit, OPS untuk digunakan sebagai pengganti agregat kasar dalam pengeluaran konkrit dapat dijamin. Disebabkan kos bahan mentah dalam industri konkrit semakin tinggi oleh itu memanipulasi bahan buangan adalah cara yang terbaik dalam mengurangkan kos konkrit. Penggunaan OPS dalam konkrit juga membantu untuk menyelesaikan masalah alam sekitar yang disebabkan oleh pembuangan sisa bahan yang tidak sepatutnya. Penambahan OPS sebagai gantian kepada agregat kasar menghasilkan konkrit ringan yang menjimatkan kos. Tesis ini menerangkan ujian yang dijalankan ke atas konkrit iaitu ujian mampatan gabungan ujian lenturan dan ricih. Spesimen konkrit yang terlibat dalam kajian ini ialah kiub bersaiz 100 mm × 100 mm × 100 mm dan papak bersaiz 350 mm × 500 mm × 100 mm. Tiga komposisi campuran konkrit yang berbeza telah disediakan iaitu konkrit tanpa penambahan OPS (kumpulan 1,B1), konkrit dengan penambahan OPS sebanyak 50% (kumpulan 2, B2) dan konkrit dengan penambahan OPS sebanyak 100% (kumpulan 3, B3). Kekuatan mampatan kiub diuji pada hari ketujuh dan hari kedua puluh lapan. Keputusan menunjukkan bahawa peningkatan dalam penggantian peratusan OPS menurunkan kekuatan mampatan. Papak konkrit pula diuji untuk melihat keretakan bawah ricih. Kajian menunjukkan peningkatan kandungan OPS di dalam papak konkrit tidak member kesan yang ketara kepada peningkatan beban kegagalan ricih.
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| | |
|---|---|
| $f_{cu,ave}$ | Average Compressive Strength |
| $f_{cu}$ | Compressive Strength |
| $\delta$ | Deflection |

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| BS | - | British Standard |
| CAR | - | Coarse Aggregate Replacement |
| CSA | - | Crushed Stone Aggregate |
| LWA | - | Lightweight Aggregate |
| LWC | - | Lightweight Concrete |
| OPC | - | Ordinary Portland cement |
| OPS | - | Oil Palm Shell |
| OPSC | - | Oil Palm Shell Concrete |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

Concrete is the most important material in civil engineering industry. It is a composite material made up from cement that acts as binders and other cementitious material, coarse aggregate such as the granite stone, fine aggregate such as natural sand and water. In addition, there are several other materials, called additives that may be added to obtain special properties of concrete. These includes accelerators, retarders, air entraining agents, water-reducing agents and superplasticizer admixtures, among others. They are needed in the right proportion depending on the strength requirement of concrete. Most application of concrete can be seen as a building material. All important building elements such as foundation, column, wall, slab and roof are made from concrete. Other concrete applications can be seen as a road, pavement, runaways, bridges and dams.

For a sustainable development of structural engineering, many research efforts have been made to find alternative basic materials which are used in construction from past many years. A properly processed of waste materials such as oil palm shell, coconut shell, rubber tyre and fly ash will produce materials that meet the design specifications (Mannan and Ganapathy,2003). In this research, oil palm shell (OPS) as a coarse aggregate replacement is the one that is being referred to. However, concrete made up from oil palm shell is different from the conventional concrete in terms of the constituents' materials. OPS replace coarse aggregate in this type of concrete.

Malaysia is one of the largest palm oil producers and exporter in the world. It accounts for over half of the world's total palm oil output and is set to grow further with the global increase in vegetable oil demand (Mannan and Basri, 1998).

However, excessive waste products are generated and left to rot in large amounts and sometimes disposed through incineration which can cause pollution to the environment. The use of waste materials in concrete industry saves natural resources and dumping spaces, and helps to maintain a clean environment.

## 1.2 PROBLEM STATEMENT

The continuous usage of raw materials in the production of concrete may cause a depletion of natural resources someday. Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the universe for years. These wastes may cause a waste disposal crisis and therefore contribute to the environmental problems. The wastes if left untreated can cause land, water and air pollution.

There was reported that an approximately 3 million tons of waste product derived throughout the electricity generated process in Malaysia (Lau, 2004). The mass production of waste material will harm our environment if no proper treatment taken to reduce it. Due to the increasing cost of materials cause by the continuous depletion of natural resources, construction material that depends on natural resources does not have consistent price in market.

Many research efforts have been made to exploit these wastes into a potential alternative construction material. In this current research, manipulating OPS as a coarse aggregate replacement in concrete is the best step in a way to lessen the negative effect to the environment. The utilization of OPS aggregates in concrete gain the economical achievement especially in reducing the market price of construction materials. OPS develops into a lightweight concrete which is a very cost effective construction materials as it can occupy about 40% of total volume concrete saving the conventional stone aggregates. Hence, this study is purposely carried out to find solution to reduce the cost of concrete production.

## 1.3 RESEARCH OBJECTIVES

The objectives of this research are to:

i. To determine the potential of oil palm shell as a coarse aggregate replacement in lightweight concrete aggregate.
ii. To study the structural behaviour of concrete slab with the addition of oil palm shell.

## 1.4 SCOPES OF RESEARCH

The research scopes includes:

i. Concrete grade C30 is used in this whole research for cubes and slabs.
ii. The type of lightweight aggregate used in this research is oil palm shell.
iii. The size of specimens used in this research are:
   a) Cube - 100 mm × 100 mm × 100 mm
   b) Slab – 350 mm × 500 mm × 100 mm
iv. Tests will be carried out to determine the performance of OPS concrete which are:
   a) Compressive Strength Test – Cube specimens
   b) Combined Bending and Shear Test – Slab Specimens
v. The coarse aggregate replacements used in this research are 50% and 100%.

## 1.5 RESEARCH SIGNIFICANCE

The main purpose of this research is to minimize the cost production of concrete using the waste material that can be found in our country. Besides that, using the waste materials from mills will reduce the by-product that thrown away by industries thus lowering the pollutions cause options. The use of OPS in construction will lower the percentage use of coarse aggregate thus the cost production will be lower since the price of OPS is cheaper. Moreover, the alternative taken from the waste materials disposal into a more environmental friendly concrete is another additional significance of this research.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter describes the nature of oil palm shell (OPS) used in the concrete production as a replacement of conventional coarse aggregate. The OPS has becoming one of the most popular alternatives to replace coarse aggregate in concrete due to its low cost and high availability in Malaysia. Material recovery from the conversion of waste materials from the agricultural and industrial based into useful construction materials has gain benefits in reducing cost of construction materials and preserving the natural resources (Mannan and Ganapathy, 2003). That is why research efforts on the effective utilisation of various types of solid wastes had gained greater attention in the past several decades.

In this chapter, the review on properties of OPS lightweight concrete is discussed. The addition of OPS to the concrete produces lightweight concrete with properties differs from the normal concrete. In addition, comparison has been made between the physical and mechanical properties of OPS aggregates and granite stone. Previous research by Shafigh (2011) showed that it was possible to develop high strength lightweight concrete using OPS aggregates to get the strength between 43-48 MPa.

## 2.2 LIGHTWEIGHT AGGREGATE IN CONCRETE

The production of lightweight concrete can either by the utilization of lightweight aggregates, the incorporation of voids by aeration and the addition of little or no fine aggregate at all. In this study, the lightweight concrete with the insertion of lightweight aggregate is one that is being referred to. The real definition for lightweight aggregate is an aggregate that weighs less than the usual rock aggregate. A reduction in density is mostly achieved by partial or full replacement of the normal weight aggregate (NWA).

Zulkarnain and Ramli (2008) in their study defined the lightweight aggregate concrete as a concrete having an air-dry density below 1850 $kg/m^3$ whereas for normal concrete the density was reported about 2300 $kg/m^3$. British Standard BS EN 13055-1:2002: Lightweight aggregate for concrete, mortar and grout defined lightweight aggregate as any aggregate with a particle density of less than 2000 $kg/m^3$ or a dry loose bulk density of less than 800 $kg/m^3$.

There are varieties of lightweight aggregates that can be used to manufacture lightweight concrete. Some of them are originated from natural materials like volcanic pumice, the thermal treatment of natural raw materials like clay, slate or shale and the manufacturing of industrial by-products such as fly-ash. In this study, lightweight aggregate from the industrial by-products is one that is being referred to.

Lightweight aggregate possessed several characteristics that made it different from conventional aggregate. Clarke (1993) reported that most lightweight aggregates were manufactured and therefore careful production control, uniform and consistent is significant for mixing, placing and compaction. It was also reported that the higher porosity of the aggregate can lead to a lower thermal conductivity, density and strength of lightweight concrete made with it. Shirley (1975) in her study said that the less porous lightweight aggregate can produce concrete which is strong enough to resist stresses applied to it.

The lightweight aggregate concrete can be divided into two types in accordance to its application (Samidi,1997).One is partially compacted lightweight aggregate concrete and another one is the structural lightweight aggregate concrete. The partially compacted lightweight concrete is mainly used for precast concrete blocks and cast in-situ roofs and walls. Meanwhile, structural lightweight aggregate concrete can be used with steel reinforcement as to have a good bond between the steel and the concrete.

One of the most highlighted benefits using lightweight aggregate is the reduction in dead loads of concrete which consequently make it economical in terms of savings in foundations and reinforcement. The advantage of weight saving is most obvious for structures with a high dead to live load ratio for example long-span bridges. Next, the exploitation of lightweight aggregates that originated from waste materials or industrial by products such as palm kernel shell and saw dust is in line with the government policy to develop more sustainable construction. The utilisation of waste materials also saves the space for dumping unutilised waste products to the rivers and lakes by the nearby factories and thus avoids the pollution of land, water and air. In addition, the use of lightweight aggregate can improve the thermal properties and fire resistance of concrete. Such application of lightweight aggregate concrete can be seen in the housing construction.

## 2.3 OIL PALM SHELL OVERVIEW

Oil palm shell, an agricultural solid end products of oil palm manufacturing processes, is actually the hard endocarp that surrounds the palm kernel shell as shown in Figure 2.1. In Malaysia, oil palm fruits can be classified as *dura,tenera* and *pisifera*. There are some characteristics between these three species that make them differ from each other. *dura* is a homozygous dominant with thick shells while *pisifera* is a homozygous recessive without shells. A ring of fibres called “mesocarp” surrounds the kernel. *dura* is cross-pollinated with *pisifera* to produce heterozygous *tenera* with an intermediate shell thickness surrounded by a ring of fibres in the mesocarp. The illustration of the OPS species is shown in Figure 2.2.

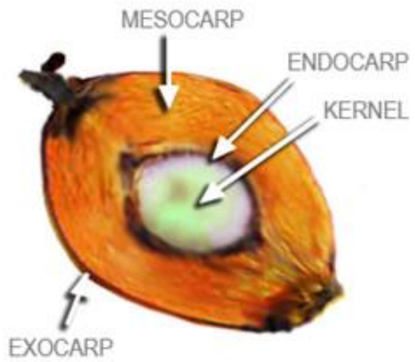


**Figure 2.1:** Cross-section of OPS

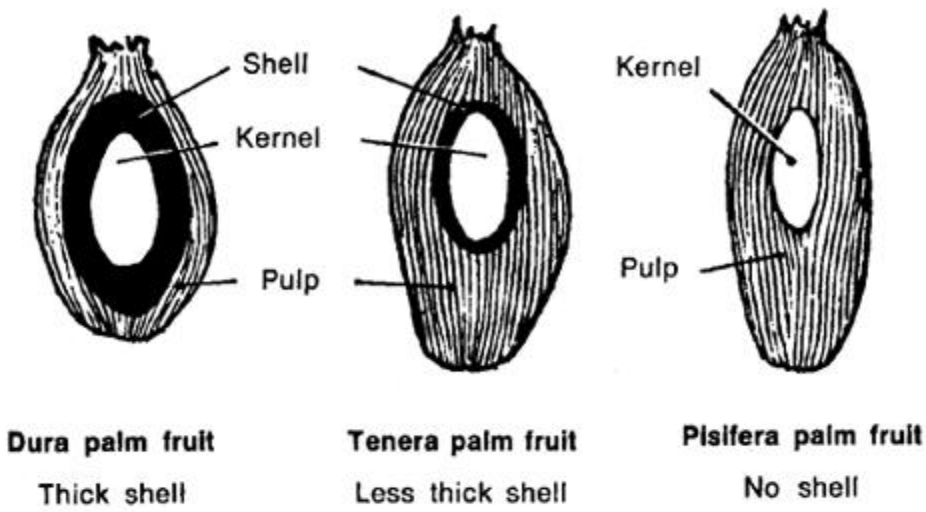


**Figure 2.2:** Ilustration of *dura, tenera* and *pisifera* OPS species

### 2.3.1 Oil Palm Shell Lightweight Concrete

Malaysia is one of the developing countries that has enormous agricultural and industrial wastes. As one of the largest oil palm producer in the world, Malaysia has total planted area coverage of 3.8 million hectares and produces over 4 million tonnes of oil palm shell (OPS) annually (Teo et al., 2006).

There are many factors leading to the increased waste production in the recent years such as the exponential growth rate of population, development of industry and technology and the growth of social civilisation. Some strategies have been undertaken in order to lessen the solid waste problems. One of them is the manipulation of properly processed materials as raw materials in the construction industry.

According to Desai (2006), a real definition of lightweight concrete is one that includes an expanding agent which increases the volume of the mixture while reducing the dead weight. It is lighter than the conventional concrete with a dry density of 300 $kg/m^3$ up to 1840 $kg/m^3$. Lightweight concrete can either be lightweight aggregate concrete or foamed concrete. A variety of lightweight aggregates can be used to produce lightweight concrete aggregate.

The inclusion of OPS as an aggregate in the concrete produces lightweight concrete because OPS is lighter than conventional coarse aggregate. Teo et al. (2006) in his research said that lightweight concrete OPS is able to produce concrete with strength of 25 MPa and above. Conventional concrete using conventional coarse aggregate has a low strength-weight ratio when compared to steel. It causes an economic disadvantage when it is used in designing structural members for tall buildings, long span bridges and floating structures. Utilisation of waste materials in producing lightweight concrete helps in providing a significant saving in the overall cost of construction and reducing solid waste that caused environmental problems.

Previous research by Shafigh (2008) was to develop high strength lightweight concretes using OPS as lightweight aggregate and to determine the influence of curing conditions on the compressive strength of high strength OPS concrete. Experimental research was done with eight different OPS concrete mixtures. All concrete specimens were cured under five different types of curing conditions. The result showed that 28-day compressive strength of OPS concretes vary around 43-48 MPa. It showed that these concretes are high strength. Hence, it can be concluded that the production of high strength lightweight concrete using OPS is possible.

### 2.3.2 Properties of Oil Palm Shell

Mannan and Ganapathy (2003) had done some research investigations to determine the physical and mechanical properties of OPS aggregates. The properties of OPS aggregates were compared with the crushed granite as in Table 2.1.

**Table 2.1:** Comparison of OPS and granite properties

| Physical and mechanical properties | Granite | OPS |
|---|---|---|
| Maximum size (mm) | 12.5 | 12.5 |
| Specific gravity (saturated surface dry) | 2.61 | 1.17 |
| Water absorption for 24 h (%) | 0.76 | 23.3 |
| Aggregate abrasion value, Los Angeles (%) | 24.0 | 4.80 |
| Bulk density (compacted) kg/$m^3$ | 1470 | 590 |
| Fineness modulus (F.M) | 6.33 | 6.24 |
| Flakiness index (%) | 24.94 | 65.2 |
| Elongation index (%) | 33.38 | 12.4 |
| Aggregate impact value (%) | 17.29 | 7.86 |

Source: Mannan and Ganapathy (2003)

Fresh concrete is said to be workable when it is easily placed and fully compacted without having any segregation or bleeding. In their previous research, Mannan and Ganapathy (2003), had prepared several mix proportions of normal concrete and OPS concrete to study their engineering behaviors. When comparing the results of workability, the fresh OPS concrete had shown marginally better workability than that of normal concrete. Other than slump and compaction factor for the same water to cement ratio, the smooth surfaces of OPS may have led to a better workability of fresh concrete. The workability of fresh concrete depends mainly on the materials, mix proportion and environmental condition. In general, most aggregates occupy about 70% of the total volume of concrete.

Mannan and Ganapathy (2003) did an experimental research to compare the compressive strength behaviour of normal concrete and OPS concrete. From the research, the developed compressive strength for 28 days samples of OPS concrete were lower than that of normal concrete. The development of compressive strength in OPS concrete was about 49-55% lower than that of normal concrete.

In general, the strength of concrete decreased when its density decrease. It is well aware that OPS concrete was lighter than normal concrete. Besides, the strength, stiffness, thickness and density of OPS aggregate are also lower than that of crushed stone aggregate which are the governing factors for the compressive strength in concrete.

## 2.4 CURING OF CONCRETE

Curing is one of the important parts in concrete production and it can be best described as a process in which a concrete is kept moist and warm enough to ensure the hydration of cement take place. Curing gives a strong influence on the properties of hardened concrete because a proper curing will increase durability, strength, abrasion resistance, volume stability and resistance to freezing. Curing is also a key player in mitigating cracks, which can severely affect durability.

Shafigh et al. (2014) in his research investigated the effect of the curing environment on the 28-day compressive strength of OPS concrete with crushed OPS aggregate. The concrete specimens were cured under five curing regimes which are fully immersion in water until the age of testing, air curing and curing in water for 6, 4 and 2 days respectively. The experimental results reported that concrete specimens under fully curing had the highest 28-day average compressive strength followed by 6, 4 and 2 days of curing and air curing respectively. The results concluded that poor curing would marginally decrease the compressive strength of concrete. Table 2.2 lists the advantages and disadvantages of different curing types whereas Figure 2.3 to Figure 2.7 show the various methods of curing.

**Table 2.2:** Advantages and disadvantages of different curing types

| **Curing type** | **Advantages** | **Disadvantages** |
|---|---|---|
| Membrane curing | • It reduces evaporation.<br>• It protects concrete surface from weathering. | • It reduces strength of concrete.<br>• It offers high cost. |
| Ponding method | • It helps in cement hydration process.<br>• It is advantageous for horizontal surface. | • It requires plenty amount of water.<br>• It cannot be used in vertical surface. |
| Steam curing | • It takes less time for concrete to cure compared to others.<br>• Steam curing is better in cold weather. | • It requires high cost as curing is done in temperature above 22 ºC.<br>• Steam curing method cannot be applied in large surface. |
| Sprinkling water | • Concrete never dries as water is applied frequently. | • It is costly because it requires a huge amount of water. |
| Wet covering | • Add moisture to the concrete during early hardening.<br>• Absorption of the heat of hydration. | • Requires plenty amount of water.<br>• Concrete surface is not allowed to dry even for a short period of time during curing period. |

Source: Carns (2010)